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UNINHABITED COMBAT AIR VEHICLES AND COMMERCIAL SATELLITES: "THE MISSING LINK"

by

Mark Nichols, Lt Col, USAF

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Advisor: Theodore C. Hailes

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Preface

The inspiration for this research occurred only after arriving at the Air War College and getting selected for the research seminar on Technology and Strategy offered by Dr. William Martel and Colonel (Ret) Theodore Hailes. During the course of our class discussions on the impact of science and technology on U.S. national security policy, it was apparent that how critical satellite communications will be for future aircraft, whether manned or unmanned. As an aviator, I have always had an interest in flying and this research offered me the opportunity to explore an area in our Air Force that I was not familiar with, namely unmanned aerial vehicles (UAV) and satellites. This paper will make two contributions: first, it will highlight the newest evolution in UAVs that is already in works within the aircraft industry and endorsed by the Air Force for exploitation, the Uninhabited Combat Air Vehicle (UCAV). Second, it will argue that the military satellite communications network envisioned for this vehicle is inadequate without the help from the commercial satellite industry.

I am indebted to Mr. Tom Blake from the Rome Laboratory Space Communications Branch for providing as much information as possible on the UCAV system and its expected operational mission. I would also like to thank Dr. Martel and Colonel Hailes for their encouragement, insight, editorial assistance, and most of all their patience. Finally, I would like to thank my wife Libby for her support and encouragement.

Abstract

In the not too far distant future, a new Uninhabited Combat Air Vehicle (UCAV), a cousin of the UAVs flying over Bosnia today, is destined to fly the most sensitive and dangerous missions the USAF is expected to accomplish. This vehicle, though uninhabited, will not operate in a vacuum, but instead will be supported by the most sophisticated network of satellite communications the nation can offer. Today, as our engineers develop a concept that will fly in the first quarter of the 21st century, most of the satellites that will be used to support this aircraft are already in design or in orbit. The Air Force Space Architecture Plan, released in 1996, projects that during the time frame that the UCAV is envisioned to be operational, the U.S. military satellite communications network will be operating.

This paper examines the risk mentioned in the space architecture plan. It argues that the use of the newest commercial satellite constellations already in the process of being launched gives the DOD a unique opportunity to meet the warfighter's needs, and argues that commercial low earth orbiting (LEO) satellites is an integral part of the DOD's strategy for the UCAV. The exploitation and partnership with the civil community offers the U.S. a reliable and redundant backup capability by utilizing the technology enhancements already funded and marketed by the commercial space industry. The integration of commercial satellites is the UCAV's "Missing Link".

Chapter 1

Introduction

Victory smiles upon those who anticipate the changes in the character of war, not upon those who wait to adapt themselves after the changes occur.

—Giulio Douhet

Unmanned Aerial Vehicles (UAVs) have been a hot topic since the end of the Gulf War, but the concept is not new. In fact, military interest in this area goes back as far as the late 1950s.[1] The difference today is that the Gulf War "appears to have validated the operational employment of UAVs in combat."[2] During the Gulf War, forty-three Israeli-designed Pioneer UAVs flew 330 intelligence gathering and reconnaissance missions supporting Army, Navy, and Marine forces.[3] The payoff to the theater commanders was a resounding success. Now, just six years after the Gulf War conflict, we have spent millions of dollars standing up our first squadron of UAVs which are flying operational sorties in support of NATO forces in Bosnia. Recently, we have taken the UAV idea one step further with the evolutionary step toward the Uninhabited Combat Air Vehicle (UCAV).

One only has to look at where the aerospace industries are investing their research money to see into the future.[4] Based on their research investments, the military community can foresee new high performance, uninhabited aircraft executing missions deemed too sensitive or too well defended for the manned fighters in the near future.[5] In summary, a UCAV is a high performance, pilotless vehicle that will accomplish the most dangerous missions. It is estimated by the commercial industry that this aircraft could be operational in the first quarter of the twenty-first century.[6] The United States military must exploit emerging UCAV technology and to do that, it must be integrated with commercial communication systems in order to meet the joint warfighter's needs in the twenty-first century.

The purpose of this study is not to discuss the relevance of UCAVs on the modern battlefield or to question their operational efficacy. Clearly the technology has evolved sufficiently so the focuses will be on communication links, specifically, the satellite requirements and commercial opportunities that will make this concept a viable and robust system in the future. This paper will argue that the newest family of commercial satellites, those that will be launched over the next several years, offer the redundancy, robustness, and survivability that the UCAV system demands. It will also point out that the UCAV requirements coincide with a period that the Department of Defense (DOD) space architect has defined as a period in which we find our military satellite network at some level of risk. This risk will be caused by expected failures on the launch pad to get new satellites into orbit and on-orbit failures of existing systems due to age. The flexibility of the UCAV mission will demand readily available, survivable, and on-demand global support systems that these commercial satellites will offer.

Tomorrow's highly technical UCAV will not be a stand-alone system. It will depend on long-range external communications via satellites to make it tactically sound. Both *Joint Vision 2010* and the Air Force's *Global Engagement Vision for the 21st Century Air Force* depend heavily on achieving global military dominance by leveraging technology with new operational concepts. Commercial satellites linked to uninhabited combat air vehicles appear to be one of those new operational concepts ripe for exploration. Partnership within the civil and military space communities has been going on for several years; however, the distinction between commercial and military communications systems is starting to blur, especially with regard to satellite communications.[7] An excellent example of this is the Air Force's interim dependence on commercial satellites to bring the Global Broadcast System (GBS) on-line.[8] The following essay argues that commercial satellites are the true "missing link" in our nation's quest for a flexible, robust UCAV program.

Section 2 will discuss some of the basic assumptions about Uninhabited Combat Air Vehicles. It will briefly discuss their potential mission, a notional vehicle, and outline some of the command, control, and communication (C3) requirements for an operational system.

Section 3 will describe the new space communications architecture for the period 2010-2025 that was recently released by the Department of Defense. This new architecture spans the Military Satellite Communications (MILSATCOM) requirements during the period in which the UCAV is expected to mature. This section will also examine two military satellite systems capable of operating with the UCAV.

Section 4 will discuss the expanding commercial satellite industry. It will discuss frequencies, available data rates, and the unique attributes of Low Earth Orbits (LEOs) which many of the new commercial satellites will occupy. It will also give a time-line of the predicted operational dates for many of the systems.

Section 5 will analyze the implications of using commercial satellites as primary or redundant backup systems for communication links to future UCAVs. It will also address technological challenges our nation will confront and the concept of operations it should adopt to make this a viable alternative.

The final section outlines recommendations for bringing commercial satellites on line for the Air Force's use. It advocates making commercial satellites systems an integral part of DOD's strategy. As the lead service in charge of developing space, the Air Force should explore the unique capabilities of commercial satellites in relation to UCAVs. To successfully integrate the UCAV into our nation's future, the Air Force needs to start developing its commercial satellite links and industries now to ensure they will be mature when needed.

Notes

[1] Lt Col Dana A Longino, *Role of Unmanned Aerial Vehicles in Future Armed Conflict Scenarios* (Maxwell AFB: Air University Press, 1994), 1.

[2] Secretary of Defense Dick Chaney, "Conduct of the Persian Gulf Conflict, An Interim Report to Congress", July 1991, 6-8.

[3] Lt Col Dana A Longino, *Role of Unmanned Aerial Vehicles in Future Armed Conflict Scenarios* (Maxwell AFB: Air University Press, 1994), 9.

[4] David A. Fulghum, "Unmanned Strike Next for Military", *Aviation Week & Space Technology*,2 June 1997,47.

[5] Stacey Evers, "Unmanned Fighters: Fight Without Limits", *Jane's Defense Weekly*, 10 April 1996,28.

[6] Ibid.

[7] General Thomas S. Moorman Jr., "The Challenges of Space Beyond 2000", remarks to the 75th Royal Australian Air Force Anniversary Airpower Conference, Canberra Australia, 14 Jun 96, on-line, Internet 1 October 1997, available from http:/www.dtic.mil.

[8] *The Air Force Issues Book*,1997, 44.

Chapter 2

UCAV Background

Before discussing the commercial satellite command, control, and communications possibilities in relation to UCAVs, a common understanding of the UCAV mission must be established. This mission will determine the need for a satellite system that is both flexible and robust.

Studies indicate that the suppression of air defenses and deep penetration strikes will be the UCAV's most critical mission.[1] In addition, it is likely that UCAVs will be employed in reconnaissance and intelligence gathering platforms with missions similar to the UAVs that are being used successfully over Bosnia today. In August 1997, the Air Force signed a memorandum of agreement with the Defense Advanced Research Projects Agency (DARPA) to initiate the development of a multiphase UCAV program.[2] Aerospace industry sources estimate that the resulting UCAV could be available for service around 2015[3]. According to the Rome Laboratory Space Communications Branch, during a typical mission a UCAV would be capable of flying at least 1000 miles, loitering, dropping weapons, performing Bomb Damage Assessment (BDA), dropping weapons again, and then returning to its base.[4]

UCAV Requirements

Beyond Line-of-Sight, two-way communications are essential to making these predictions come true. During a typical mission, communication requirements might include: control communications from a ground control station to the UCAV, feedback/telemetry communications from the UCAV to the ground control station, target data communications to a ground control station, weapons release data from the ground control station to the UCAV, and finally, BDA data transmitted back to the ground control station.[5] Additionally, if reconnaissance and intelligence missions are also desired, other data links, such as off-board sensors to the ground control station or to the UCAV, will probably be needed. To improve and increase reliability, all of these exchanges will most likely be broadcast over UHF and higher frequency ranges to provide high data rate transmissions.[6]

These basic communications requirements make satellites a critical link throughout the entire process. While this is not an exhaustive list of requirements, it highlights the magnitude of information flow that is envisioned for UCAV operations. In simple terms, this means that UCAVs will need two-way low-and high-data rate communications with ground control stations for the primary attack mission to be successful.[7] Notional data rates required to and from a UCAV are estimated to be at least in the megabit range.

UCAV communication requirements are derived from the vehicles mission and design. A notional vehicle designed to perform the UCAV mission would, most likely, weigh less than 10,000 pounds, have supersonic capabilities, operate in the 30,000 feet regime, and incorporate low observable characteristics.[8] All of these characteristics need to be considered when designing compatible communications systems. The low observable aspect of the design will probably present the greatest challenges.

Many of the leading engineers in the aerospace industry believe communications will be the critical technical factor in designing the UCAV system.[9] The technology revolution underway in the satellite communications industry today is essential to the UCAV's success. Both military and civilian satellite communications industries have made tremendous gains in their development of satellite systems. Some already exceed the capacity to handle the UCAV requirements. In fact, the DOD has projected that future satellite data-rate capabilities will increase to allow 1.5 billion bits/second to be transmitted by the end of 1997.[10] High data rates are essential for real-time interactive command and control systems like fight controls and video reception and transmissions.

Notes

[1] David A. Fulghum, "Unmanned Strike Next for Military", *Aviation Week & Space Technology*, 2 June 1997,47.

[2] David A. Fulghum, "Flying Slots Disappear, Shift to Ground and Space", *Aviation Week and Space Technology*, 15 September 1997, 74.

[3] David A. Fulghum, "Unmanned Strike Next for Military", *Aviation Week and Space Technology*, 2 June 1997, 47.

[4] Major Tom Blake, Rome Laboratory, Space Communications Branch, Fax, 23 October 1997, 1.

[5] Major Tom Blake, Rome Laboratory, Space Communications Branch, Fax, 23 October 1997, 1.

[6] Data rate is defined as the number of equivalent binary digits transferred per second and is measured in bits per second (bps). Low data rate (LDR) is the ability to transmit and receive between 75-2400 bps.[6] Medium data rate (MDR) is 2400 bps-1.544 Mega bits per second (Mbps) or 10 to the sixth power.

[7] Major Tom Blake, Rome Laboratory, Space Communications Branch, Fax, 23 October 1997, 1..

[8] Major Tom Blake, Rome Laboratory, Space Communications Branch, Fax, 23 October 1997, 1.

[9] According to James Bledsoe, the manager of advanced strike systems at McDonald Douglas Phantom Works, "we must make progress [beyond current systems] for the UCAV concept to work."

Notes

[10] Lieutenant Colonel Robert E. Johnson, USA, "Infomation Warfare: Impacts on Command and Control Decision Making", *Defense Tactical Information Center (DTIC)*, 15 April 1996, 21.

Chapter 3

Space Communications Architecture

> *The service is committed to integrating space-based platforms with air-breathing sensors into an architecture that supports the information needs of our joint force commanders.*
>
> —SECAF Sheila Widnall

The first man-made communications satellite was launched in December 1958, but functioned for only 12 days until its batteries failed.[1] Today, almost 40 years later, the United States military depends heavily on satellite capability. In the 40 years since Sputnik, civilian space companies and military space programs within the United States have matured basically unilaterally. Only until recently, with the decline of the defense budget and the disappearance of a true peer competitor have these two organizations begun cooperative efforts as a more efficient means of achieving their goals. The first step toward this end is defining space requirements that the military recently undertook. In 1996, the DOD completed a yearlong project designed to define the optimal space architecture for military use in 2010-2025. The project task was to develop a plan to integrate space systems, eliminate “stove-piping”,[2] and achieve efficiencies in acquisition through program integration. Achieving these three goals would improve space support to military operations.[3]

When published in 1997, this report advocated a communications plan that encompassed four core DOD capabilities, commercial augmentation, and a global broadcast capability.[4] The first core DOD capability is a new, extremely high frequency system for secure transmission.[5] The second capability requires a system to meet the demand for high capacity communications systems for global broadcast. The third requirement or capability is to provide a mobile communications service unique to the military, and the last core capability is to provide secure communications to the most remote geographic regions.[6]

Although the final report does not specifically address commercial satellite development in detail, it argues that commercial systems will play a significant role in military plans as the technological advances anticipated over the next several years materialize. The commercial advances anticipated include: crosslinks, increased processing, large constellations in varied orbits, and low cost, and low maintenance terminals, all of which are discussed later.[7]

If the approved Air Force communications architecture is not altered, there will be at least four gaps in the requirements envisioned for UCAV operations between 2003 and 2015.[8] These shortfalls are in the areas of secure communications, the inability to provide a mobile-netted communications system, satellite availability for global broadband broadcasting, and finally, the lack of a robust polar orbit system when required.[9] Polar orbits are essential in covering the poles and providing long dwell times over the Northern Hemisphere where many missions could be conducted.

As currently written, the USAF-approved communications architecture does not provide this country with the military systems needed to support the envisioned UCAV program without significant support from commercial industry. In fact, during the period between 2003 and 2015, the space architecture report argues that military satellite communications will be operating in a period of accepted risk as our primary platforms are evolving.[10] In this case, "accepted risk" refers to the lack of the necessary military systems in orbit as a result of projected launch failures or systems failures due to age.

The new space architecture relies on MILSTAR and the Global Broadcast System (GBS). The MILSTAR is designed to provide survivable, robust, and flexible communications capabilities under the harshest conditions, including jamming, interception, and nuclear radiation.[11] Flexibility is the ability to provide global access to all customers and systems when needed.

When it becomes operational in fiscal year 2001, MILSTAR will consist of four satellites, each in a geosynchronous earth orbit (GEO) that is 22,238 miles above the earth's equator and remain in that position above the earth's surface.[12] Constellations in this orbit can cover the earth with fewer satellites given each satellite's wide area of coverage; hence, MILSTAR only has four satellites. Each satellite will also have inter-satellite crosslinks enabling one ground station to control of all four satellites from one ground location.[13] These crosslinks are expensive, highly complex procedures that allow satellites to communicate with each other without having to bounce a signal off the ground. They are essential to the flexibility that is needed in the UCAV program.

Unfortunately, this type of orbit presents a huge drawback to UCAV operations. The built-in time delay for a signal to travel from the earth to the satellite and back to the earth is commonly referred to as latency. In GEO orbits, satellites have a 0.24-second latency for signals.[14] For a computer, a quarter of a second delay is an inordinately large length of time in the exchange of data between systems. This inherited GEO problem could limit command and control of an interactive system. Because tactical communications is one of this system's primary functions, MILSTAR will be uniquely suited to support the UCAV program given its capability to transmit both low data rate and medium data rate signals to its users.[15] However, it will prove less useful for command and control in view of the latency problem discussed above.

Another military satellite constellation that could be used to support the UCAV program is the Global Broadcast System (GBS). Once deployed, the GBS will provide nearly worldwide, high capacity, one-way transmission means for a variety of data, imagery, and other information that is required to support military operations.[16] The GBS will operate on government and commercially leased satellites stationed in GEO orbits, each of which will provide coverage from 65 degrees north latitude to 65 degrees south latitude.[17]

The current program and budget call for the GBS program to be implemented in three phases. Phase I commenced in 1996, when commercial satellites were leased to provide a test-bed for defining requirements and refining those into operational concepts.[18] In phase two, which will take place between 1998-2006, military satellites will be launched and augmented by commercial satellites to provide a near worldwide GBS capability. Finally, Phase Three will start in 2006 when military satellites, whose architecture is still in the planning phase, will be launched.[19] Of particular interest to UCAV operations is the fact that GBS is a one-way communications system. It will not be capable of the two-way communications required for command and control of a UCAV. It will, however, be ideal for providing tactical information products such as video and imagery, which are the UCAV's secondary missions.[20]

Notes

[1] Donald H. Martin, *Communication Satellites 1958-1995*, May 1996,3.

[2] Stove-piping is a term often used to describe an organization hierarchy in which information is not distributed evenly upward or downward and instead of flowing out to all levels, stays in a relatively confined space.

[3] "Space Communications Architecture", 29 August 1996, 1, On-line, Internet, 6 November 97, available from http://www.acq.osd.mil/space/architect/space.html.

[4] Ibid.

[5] Ibid., 2-4.

[6] Ibid.

[7] Ibid.

[8] Ibid.

[9] Ibid.

[10] Ibid.

[11] Donald H. Martin, *Communication Satellites 1958-1995*, May 1996,171.

[12] Ibid.,172.

[13] Ibid.

[14] On-line, Internet, www.byte.com, John Montgomery, "Fiber in the Sky", Byte, November 1997, 68.

[15] Donald H. Martin, *Communication Satellites 1958-1995*, May 1996,173.

[16] On internet, *Global Broadcast System Requirements Document (SRD), System Overview*, 3. www.fas.org/spp/military/program/com/gbs_srd.htm, 20 Oct 97.

[17] Ibid.,4.

[18] On internet, Global Broadcast Service (GBS) (Space), "Mission description and Budget Item Justification," 1, www.fas.org/spp/military/budget/peds_98f/0603854f.htm, 20 Oct 96.

[19] On internet,Global Broadcast Service (GBS) (Space), "Mission description and Budget Item Justification," 1, www.fas.org/spp/military/budget/peds_98f/0603854f.htm, 20 Oct 96

[20] On internet, *Global Broadcast Service Joint Operational requirements Document (JORD)*, *Operational Concept*, 3, www.fas.org/spp/military/program/com/gbs_jord.htm, 20 Oct 97.

Chapter 4

Commercial Satellite Attributes

It should come as no surprise that the Department of Defense depends on space to move information quickly across an entire battlefield. Desert Storm demonstrated the pivotal role that satellites will have in future conflicts as space became an area of strategic significance. As a reference point, the total national security space budget for 1997 is about $14 billion.[1] The United States Department of Commerce estimate for all commercial space activity in 1997 is about $8 billion. This number is expected to double over the next 10 years with the development of low and medium earth orbit satellites.[2] The international sector is also expanding its commercial satellite programs by spending at least another $7.2 billion during the same period of time.[3]

The attributes of commercial satellites will supplement the highly maneuverable and stealthy Uninhabited Combat Air Vehicle (UCAV), which is expected to be in service in the early part of the next century. Because of this vehicle's ability to suppress air defense and accomplish deep strike missions, it will be necessary to have continuous high technology global satellite connectivity on demand.

Background

In the 1960s and 1970s, the military dominated space technology with regard to frequency spectrum, bandwidth, computers, and signal processing. Today, however, commercial systems are outpacing military requirements and, to some extent, military technology.[4] Currently, the DOD is trying to leverage commercial off the shelf capabilities and technology to better align our future military force structure with the path that commercial technology is traveling. In an address to the National Space Forum in Washington, a senior official predicted that commercial satellites and systems will eventually provide 70 percent of the DOD's future communication needs.[5] Based on the projected importance of the civilian space program, commercial satellite attributes, such as orbits and communication frequencies, are important considerations for military planners.

Orbits and communication frequencies are the fundamental elements of any satellite system. Understanding the salient features of each are key to choosing the best system to complement UCAVs. Until recently, the military and civilian sectors were only concerned with GEO communication satellites, based primarily on their large area coverage and the relative ease of tracking them in their stationary orbits. However, with the growing number of satellites in GEO orbits, congestion and frequency deconfliction have become major problems that are forcing satellite companies to investigate and develop different options. In 1998, a new low altitude, satellite communications network designed for commercial use will offer numerous capabilities that up until now were unattainable.

Orbitology

Military planners must balance the UCAV's anticipated mission needs against several options in orbital geometry that present a variety of advantages and disadvantages. Typically, there are three orbits that satellite constellations occupy. The orbit farthest from the earth is the geosychronous earth orbit. In addition to the high latency factor (0.24 seconds), there are several other disadvantages. Satellites in this high orbit tend to be very big due to the requirement for a large power supply to send the transmissions back to earth. Consequently, it is very expensive given the heavy payload involved and the distance from the earth to their final orbit.

Another problem with this orbit is the limited number of slots available to each country. Because geosynchronous satellites are fixed over the earth's surface at similar altitudes, there is a limited number of slots available without interfering with each other.[6] Another disadvantage is that their equipment has to be hardened to avoid being damaged by radiation while passing through the Van Allen radiation belts[7]. Finally, geosynchronous satellites are not able to provide coverage over the northern and southern hemispheres because their orbits are located over the equator. While geosynchronous satellites have played an extremely important role in past communication networks and will continue to do so in the future, the advantages of the orbit do not outweigh the disadvantages encountered with respect to the mobile and interactive UCAV mission.

The middle orbit is called the medium earth orbit, or MEO. Satellites in this orbit travel around the earth from 6,250 to 12,500 miles above the surface.[8] Unlike the geosynchronous satellites, their relative position in the sky travels across the earth's surface. Because of their lower altitude, more satellites are required per constellation to ensure full earth coverage, but the latency of signals is reduced substantially (0.06-0.14 seconds)[9]. The trade-off between the number of satellites required for full earth coverage and the relatively low latency when compared to a GEO makes this a more advantageous orbit for UCAV communications. A major disadvantage of this orbit is the amount of “dead time” each satellite experiences as it travels across the earth’s surface. “Dead time” occurs when a satellite is over the ocean and not in a position to support operations over the land.

The last orbit, and the one that is best suited for UCAV command and control, is the low earth orbit or LEO. Low earth orbits provide extremely low latency because they normally orbit below 3,150 miles from the earth, with the majority orbiting in the 400-1,000 mile range.[10] At this low altitude, the latency of a signal is almost negligible and is measured in hundredths of seconds, which offers greater compatibility for interactive systems such as command and control of a UCAV. To maintain full earth coverage in this low-altitude orbit, a large number of satellites are required. Although this appears to be a drawback initially, the smaller size of this type satellite makes it possible to launch multiple satellites on one launch vehicle, which cuts the total cost of the constellation. This cost saving has already been demonstrated numerous times with the Iridium system, which is the name of a low earth orbit constellation of satellites that Motorola is launching. Motorola has routinely launched five satellites into orbit with the McDonnell Douglas Delta 2.[11] Another advantage that low earth orbiting satellites possess is their constellation fault tolerance is much higher.[12] Fault tolerance is the ability to continue to operate successfully if a percentage of the constellation’s satellites malfunction. Because low earth orbiting constellations have a large number of satellites that communicate with each other, they are more difficult to disable.

A problem shared by all low earth orbiting satellites is the need to compensate their position as they cross the earth’s surface. Unlike the stationary geosynchronous satellites, low earth orbiting satellites have to depend on Doppler shifts in frequencies to determine their position over the earth at any given time.[13] Another disadvantage is satellite crosslinks, which as discussed in the previous section, provide the ability to communicate directly between satellites. This is a critical factor in this orbit. Finally, low earth orbiting satellites are vulnerable to orbit decay because of their close proximity to the earth.[14] Normally, each constellation includes additional spare satellites that can be employed when needed.

Satellite Frequency Spectrum

Orbitology is not the only attribute that satellites offer the UCAV. When it comes to satellites, the orbit they occupy and the frequency that the satellite system utilizes determines their usefulness.[15] It is estimated that the evolutionary developments in broadband frequency satellite communications will revolutionize our military communications capabilities.

Radio frequency is determined by how often the crest of a radio wave passes a given point in a given period of time. Radio frequencies are measured in "hertz". The higher the frequency, or hertz, the shorter the wavelength.[16] Different wavelengths also have different properties. For instance, long wavelengths can travel long distances and penetrate obstacles relatively easily. Shorter wavelengths in the high frequency range do not retain the same amount of power over long distances and can be stopped by relatively mild obstructions such as rain.[17] Yet, while the shorter wavelengths are easily blocked, they have the capability to transmit more information than the longer wavelength in the lower frequency ranges.[18] Higher frequency ranges are the most useful for UCAVs.

Frequency Bands

The use of the electromagnetic spectrum for satellite communications has been a constant problem for military and commercial users. Many believe that the development of broadband satellite systems with the capability to transmit and receive over a wide frequency range will help future military requirements.[19] The designation of frequency ranges, or bands, dates back to World War II when United States and British radar developers named parts of the spectrum with letters.[20]

For the most part, satellites have used only a few bands of the frequency spectrum. Each of these bands has its advantages and disadvantages. The lowest frequency satellite band commonly used is the Ultra High Frequency (UHF). UHF has very long wavelengths, and is not compatible for UCAV command and control because the data rate is too slow. L-band frequencies are also used frequently. This particular band has long wavelengths, carries less data than the higher band wavelengths, and requires less powerful transmitters on-board a satellite. Most L-band frequencies have been allocated to commercial and military users.[21] Ku-band is another frequency range that is used extensively by satellites.

The new frontier for the latest generation of satellites is Ka-band with a frequency range of 18-31 GHz.[22] This band uses very small wavelengths that carry an enormous amount of data. Because of the small wavelengths, a high proportion of the spectrum is available for allocation.[23] Satellite systems using this band need powerful transmitters or should be in orbits closer to the earth, such as a LEO orbits, because the shorter wavelengths are subject to high attenuation from atmospheric conditions.

The Ka-band expansion can be traced back to NASA when it launched its first Advanced Communications Technology Satellite (ACTS) in September 1993.[24] This satellite proved that it was possible to create an on-board, all-digital, Ka-band system that could overcome the problems of attenuation that plaque the satellite community. As a result, NASA also highlighted the capability for a single satellite antenna beam to subdivide its large footprint into many smaller subfootprints (spot-beams) and focus the beams on specific areas.[25] Spot-beams have the advantage of smaller footprints, which enables the frequent reuse of the spectrum by the same satellite at the same time.[26]

The high frequency technologies demonstrated by NASA in 1993 demonstrated that remarkably high data rate capabilities can provide the impetus for a commercial LEO satellite boom. In 1997, the Federal Communications Commission (FCC) issued licenses to 13 civilian companies to operate satellite systems with a variety of broadband services using the 28 GHz frequency.[27] Additionally, there are civilian companies that are now lobbying to push the satellite frequency spectrum even further by transmitting vast quantities of data at even higher rates in the extremely high frequency range. This new band will be designated V-band and will occupy the 36-51.4 GHz range.[28]

Commercial Industry Investment

The satellite industry is definitely a growing business. Companies investing in commercial satellites are making huge capital investments in the fastest growing field in the aerospace industry. There are at least 12 new commercial satellite constellations that are scheduled to be operational by 2002.[29] About half of these commercial systems (see Table 1) have broadband capabilities, while the others are designed for specific personal communications systems. The money invested by the commercial sector outpaces the military planned expenditures by all accounts. The average estimated cost for each civilian system is approximately $3.5 billion with the lowest priced constellation costing $0.33 billion and the highest priced constellation costing $13 billion.[30]

Today, civil and military expenditures are becoming equal, but this will not last. As we look beyond 2002, the FCC has already granted commercial licenses to TRW, Hughes, and Motorola for proposed broadband satellite systems that will operate in the V-band.[31] The estimated costs of these systems are $3.4 billion, $3.85 billion, and $6.4 billion, respectively, with no end to commercial expansion in sight.[32]

Table 1. Future Commercial Satellite Constellations

	Cyberstar	**Celestri**	**Astrolink**	**Teledesic**	**Spaceway**	**Skybridge**	**Iridium**
Backers	Loral	Motorola	Lockheed	Bill Gates & Boeing	GM-Hughes	Alcatel & Loral	Motorola & Raytheon
Use	Data & video	Voice, data, video	Data, video, & telephone	Voice, data, video	Data	Voice, data, video	Voice & data
Orbit	GEO	LEO & GEO	GEO	LEO	GEO	LEO	LEO
Spectrum	Ku & Ka	Ka & 40-50 GHz	Ka	Ka	Ka	Ku	L & Ka
Data through put	30 Mbps	155 Mbps	9.6 Mbps	64 Mbps	6 Mbps	60 Mbps	2.4 Kbps
System cost (billions)	$1.05	$13	$4	$9	$3.5	$3.5	$3.7
Operation starts	1998	2002	2000	2002	2000	2001	1998
Number of satellites	TBD for Ku: 3 for Ka	63 LEOs, 9 GEOs	9	288	8	64	66

Source: "Fiber in the Sky", *Byte*, Nov 1997, 61-66, On Internet, www.byte.com

Notes

[1] Dr. Paul G. Kaminski, "A Year Later: A Report Card-Any Outside the Box Thinking", Keynote Address of the Under Secretary of Defense for Acquisition and

Notes

Technology, Presented to the 2nd Annual Space Policy and Architecture Symposium, Crystal City Marriot Hotel Arlington Va, 11 Feb 97, 2.

[2] Ibid.

[3] Ibid.

[4] General Thomas S. Moorman Jr., "The Challenges of Space Beyond 2000", remarks to the 75th Royal Australian Air Force Anniversary Airpower Conference, Canberra Australia, 14 Jun 96, on-line, Internet 1 October 1997, available from http:/www.dtic.mil.

[5] General Thomas S. Moorman Jr., "Moorman: Integrated Roadmap Need for Space", *Military Space*, Vol.14, No.12, 9 June 1997,1.

[6] Typically, satellites in GEO orbits are spaced a minimum of two degrees apart to reduce interference with each other. This information was obtained from a senior National Reconnaissance Office guest speaker speaking to the UASF Air War College on 21 January 1998.

[7] Captain Douglas K. Stenger, USAF, "Thesis-Survivability Analysis of the Iridium Low Earth Orbit Satellite Network", December 1996, Chapter 2, Literature Review, .2

[8] Ibid., 68.

[9] Ibid., 58.

[10] Ibid., 68.

[11] Joseph C. Anselmo, "Iridium Growth Spurt Tests Ground Control" *Aviation Week and Space Technology*, 21 July 1997, 58.

[12] Captain Douglas K. Stenger, USAF, "Thesis-Survivability Analysis of the Iridium Low Earth Orbit Satellite Network", December 1996, Chapter 2, Literature Review, .3

[13] Ibid.

[14] Unlike GEO satellites, satellites in LEO orbits will eventually fall to the earth due to the increased drag caused by the earth's atmosphere. Typically, a LEO satellite can stay in orbit 4-7 years before its orbit decays.

[15] [15]John Montgomery, "Fiber in the Sky", *Byte*, November 97, 58, On Internet, www.Byte.com.

[16] Ibid., 60.

[17] Ibid..

[18] Ibid.

[19] Ibid., 70

[20] Ibid.

[21] Ibid., 58.

[22] Ibid., 70.

[23] Ibid., 59.

[24] Ibid., 61.

[25] Ibid.

[26] Ibid., 61.

[27] Joseph C. Anselmo, "New Satcom Proposals to Push frontier of Radio Spectrum" *Aviation Week and Space Technology*, 15 September 1997, 27.

[28] Ibid.

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[29]John Montgomery, "Fiber in the Sky", *Byte*, November 97, 61-66, On Internet,www.Byte.com.

[30] Ibid.

[31] Joseph C. Anselmo, "New Satcom Proposals to Push frontier of Radio Spectrum" *Aviation Week and Space Technology,* 15 September 1997, 27.

[32] Ibid.

Chapter 5

"The Missing Link"

> *The Air Force has embraced the UAV. These remote controlled aircraft can collect and relay information via satellite from battlefield locations.*
>
> —Gen Ronald Fogleman

The paradigm shifts that have occurred since the end of the Cold War, together with our highly publicized victory in the Gulf War, greatly affected the U.S. military. Before the Gulf War, UAVs and satellite capabilities and connectivity to air breathing platforms were discussed only behind close doors. Today, UAVs have been accepted and are employed in Bosnia. UCAVs linked to military and commercial satellites may well be the next major step in the evolution of our technologically sophisticated forces. UAVs could very easily become the precursor to UCAVs tomorrow. But this has not occurred in a vacuum.[1] Uninhabited combat air vehicles coupled with the latest commercial satellites offer the versatility required to both maximize our capability in the air and minimize the budgetary impact. By examining specific commercial satellite constellations and their attributes, it becomes painfully clear that commercial satellites are truly the "missing link" in twenty-first century capabilities.

Low Earth Orbits verse Geosynchronous Orbits

As stated earlier, one of the biggest differences between a low earth orbit and a geosynchronous orbit is that low earth orbiting satellites are not stationary relative to the earth's surface. Specifically, the Iridium constellation of low orbiting satellites travel around the earth's surface at the speed of 16,669 miles per hour, completely circling the earth every 100 minutes.[2] Tactically speaking, it would be more difficult for an opponent to destroy or diminish the capabilities of this satellite communications system than that of a stationary geosynchronous satellite, such as one found in the Global Broadcast System constellation.

Iridium is a unique satellite system, and is the first of many commercial communications satellite systems to occupy a low orbit. The Iridium constellation will consist of 66 high-speed, primary satellites flying in 6 orbital planes around the earth.[3] Each plane will contain an extra satellite as a spare, giving the total Iridium system 72 satellites[4]. As of November of 1997, Motorola, the owner of Iridium, has 30 of 34 satellites launched and operating, and expects to have a total of 46 satellites in orbit by first part of 1998, or 65 percent of the constellation complete.[5] Motorola's announced operational date for Iridium is in the later half of 1998.

Constellations such as Iridium and other low earth orbit satellites meet this UCAV specific need. Because of propagation anomalies near the horizon, geosynchronous satellites orbiting over the earth's equator are not very effective in the far northern and southern latitudes. Consequently, if we are required to deploy to these regions 20 years from now, we may not have continuous coverage.[6]

Another major advantage that low orbiting satellites offer the UCAV is the increase in fault tolerance due to the larger number of satellites within a given coverage area.[7] In the case of the Iridium constellation, for instance, computer modeling of this multi-satellite system has shown that even with 45 percent of its satellites functioning, or 55 percent inoperative, the communications delay never exceeds 178 msecs.[8] This figure is well within the accepted tolerances for the survivability of military systems, and demonstrates that low-orbit satellites are very survivable, given their higher numbers of satellites and crosslink capabilities.[9] Low earth orbits used by our newest commercial satellites will enhance the uninhibited combat air vehicle's tactical flexibility because they are constantly on the move, provide worldwide coverage over the poles if required, and ensure survivability through the sheer number of satellites. Commercial satellites in low earth orbits will bring the military unforeseen benefits in communications capabilities by using spot beams, crosslinks, and a variety of orbits. An endorsement by the military for low-earth orbiting satellites was recently announced by Motorola boasting that the U.S. military had signed a $14.5 million contract for use of their constellation for communications purposes.[10] The 10-year project is designed to begin operations in September 1998.

Communication Capabilities

When operational, Iridium's low earth orbiting network of satellites will be the first of many commercial satellite systems capable of providing two-way voice and data communications between geographically separated users via inter-satellite links or crosslinks.[11] Each Iridium satellite will have the capability to communicate with four other satellites in different orbits around the earth.[12] This extensive network of satellites tied together with low and high data rate crosslinks in the Ka-band provides continuous communications, with very low latency, to systems such as the UCAVs flying at altitudes up to 100,000 feet above mean sea level.[13]

Low latency, high data rates, and abundance of frequencies available with low earth orbiting commercial satellites will be of tremendous value in UCAV command and control. The newest commercial satellites in low orbits will use different frequency bands than those used by geosynchronous satellites.[14] Each commercial low orbiting satellite will be equipped with spot beams that will reuse the available frequency spectrum in a very efficient manner with minimal transmission delays.[15] Some of the low earth orbiting satellites planned for operation before 2002 will be capable of a data throughput of up to 155 Mbps, which is well above the UCAV notional minimum requirement of data throughput in the megabit range.[16]

More Bang for the Buck

Since the fall of the Berlin Wall, the DOD's budget has continued to decline while technology enhancements have continued to increase military capabilities. Today more than ever, the United States military must integrate its efforts if it hopes to reap the benefits of the technology revolution taking place within this country. In 1996, then Secretary of Air Force Widnall, enthusiastically endorsed the adoption of aggressive new business practices to free funds for future priority programs.[17] The latest *Quadrennial Defense Review (QDR)* highlights the fact that the DOD budget has declined from $400 billion in 1985 to $250 billion in 1997.[18] This is only 3.2 percent of the gross national product today, compared to 7 percent in 1985, and this trend continues.[19] In his report to Congress on the *QDR*, Secretary of Defense Cohen stated that we must take advantage of the revolution in business affairs that has occurred in the last generation.[20] He predicted that if we do not, we risk failing to acquire modern technologies and systems that will be essential if U.S. forces are to successfully protect the nation's security interests in the future.[21]

The commercial satellite infrastructure is not only basic to our survival as a nation but to our continued expansion in space as well. By its very nature, the UCAV will demand integrated satellite networks that the DOD will not be able to afford without huge sacrifices. Cooperation with the commercial and international sectors will reduce the space infrastructure capital needed and consolidated functions will eliminate duplication of effort, improve efficiency, and bind all participants more closely together.[22] A great attribute of the civil side of the satellite community is their short "cycle time" or ability to move quickly from idea to a functional system in satellite development.[23] In most cases the commercial sector can field a satellite system in three years, which is considerably better that the military average of five years.[24] A partnership between the military and civilian companies is not a new concept. As seen with the Global Broadcast System, we have already agreed to lease commercial satellites as an interim solution.

With a declining defense budget, the UCAV could very well be called upon before 2015 as our leaders explore ways to save money. When asked how soon a UCAV could be operational, a manager at McDonald Douglas replied that materials, sensors, and communications are maturing nicely, and the military could field as early as 2007-2010.[25] Current aviation and technology magazines are full of articles claiming that current technology makes unnecessary to have a pilot in the cockpit.[26] The subject of UAVs versus pilot requirements will not go away, and it will be harder for the military aviation community to ignore as money becomes tighter and we are asked to do more with less. The commercial satellite industry, with thousands of satellites, could very well provide the DOD with a quick low cost solution for space-based communications control for our newest aircraft.

Security Challenges

As with any new concept there are always problems that have not been carefully examined. Obviously, communications security and satellite jamming issues are a major concern, but they are not insurmountable. Currently, the U.S. Defense Department's space architect is studying this problem. He has stated that the Pentagon could rely on commercial satellites for most of its day-to-day activities, and that even classified data, in encrypted form, could be sent over the newest commercial networks that are slated for operations in the next few years.[27] These same commercial networks are the very ones that are essential for UCAV command and control. As data rates, spot beams, and higher frequencies evolve, there is belief that military operations can be carried out with very high confidence using these commercial systems.

The biggest challenge for the operational community is to miss the larger opportunities. The military needs to look beyond our current space investment scheme and embrace the commercial market as whole-heartedly as we did the UAV. During a recent war gaming scenario for the year 2020 conducted by the "Army-After-Next" program, game participants quickly found out that strategic reserves of space systems were inadequate in the face of a nuclear blast. The game showed the value of high altitude UAVS and space based assets in the future.[28] Granted, a nuclear blast in space will destroy both commercial and military satellites, but it is unlikely to destroy thousands of them, and more specifically, it may not be able to destroy a satellite system that is designed for high survivability.

Alternative Option

There is only one viable option available for the United States government and our civil/military communities. The United States military finds itself today in a situation that rivals times past with our commercial air industry. In 1950 and 1951, U.S. military airlift was under a huge strain as it tried to transport men and equipment to the Korean theater during our military buildup for war.[29] In response to this, President Truman issued an executive order creating what is now known as the Civil Reserve Air Fleet (CRAF) to fill a void in our capabilities by enlisting help from airline industries.[30] Today, this system is still used in cases of emergency. In return for the use of their aircraft in the reserves, airlines receive peacetime government contracts for moving people and equipment.[31]

Our current situation in space is very similar to the circumstances 46 years ago. Our military budget is strained and the civil sector has the capacity that we want and need, but cannot afford. This idea is already coming to fruition as seen with the Iridium contract with the military announced in January. An opportunity exists today to create what could be known as the Satellite Air Reserve Fleet, or SRAF, to fill a void in our military responsiveness. Once instituted, the Air Force could buy or lease space from commercial satellite companies. During peacetime, government contracts for their use would guarantee their availability, while at the same time, maximize the use of all available space assets. In times of national crisis, specific satellite systems would be called as required. Using the SRAF concept, space communications could be cooperatively developed in efforts that would reduce DOD costs while increasing interoperability among those in the industry.

Notes

[1] *JV 2010* provides the conceptual framework to take joint warfighters to the next level in this realm of modern warfare.

[2] Mark Long, *The 1992/1993 World Satellite Almanac*, Mark Long, Third Edition (Winter Beach Florida: MLE INC, August 1, 1992): 263.

[3] Jeff Hunt, "Catch a Flaring/Glinting Iridium", on-line, Internet, 4 November 1997, available from http:/www.satellite.eu.org/sat/vsohp/iridium.html.

[4] Ibid.

[5] John M. Windolph, "Iridium LLC Announces Third Quarter Results". Press Release, October 1997, on-line, Internet, 17 October 1997, available from http:/www.prgguide.com/prg/newsletter/samplwes.html.

[6] Douglas K. Stenger, "Survivability Analysis of the Iridium Low Earth Orbit Satellite Network", *AFIT Thesis* AFIT/GCS/ENG/96D-26, December 1996, Chapter 1,2.

[7] Ibid.,3.

[8] Douglas Stenger, "Survivability Analysis of the Iridium Low Earth Orbit Satellite Network", *AFIT Thesis* AFIT/GCS/ENG/96D-26, December 1996, Chapter 5, 1.

[9] Ibid.

[10] Quentin Hardy, "Iridium Gets Military as First Big Customer", *The Wall Street Journal*, January 26, 1998, B7.

[11] Douglas Stenger, "Survivability Analysis of the Iridium Low Earth Orbit Satellite Network", *AFIT Thesis* AFIT/GCS/ENG/96D-26, December 1996, Chapter 2, 7.

[12] Ibid.

[13] Mark Long, *The 1992/1993 World Satellite Almanac*, Mark Long, Third Edition (Winter Beach Florida: MLE INC, August 1, 1992): 264.

[14] Ibid., 263.

[15] Ibid.

[16] Major Tom Blake, Rome Laboratory, Space Communications Branch, Fax, 23 October 1997, 1.

[17] SECAF Sheila Widnal, "Shaping our boundless Future", *Aviation Week and Space Technolgy*, April 16 1997, 27.

[18] SECDEF William S. Cohen, "Report of the Quadrennial Defense Review", *Joint Forces Quarterly* ,Summer 97, 8-14.

[19] Ibid.

[20] Ibid.

[21] Ibid.

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[22] Under SECDEF for Acquisitions and Technology Dr. Paul G. Kaminski, “A Year Later: A Report Card-Any Outside the Box Thinking”, Keynote address to the Annual Space Policy and Architecture Symposium, Crystal City, Arlington Va February 11, 1997

[23] Ibid., 4.

[24] Ibid.,4.

[25] James Bledsoe, “Unmanned Strike Next for Military”, Interview with *Aviation Week & Space Technology*, 2 Jun 1997, 48.

[26] An excellent example of this is an article in the *Staten Island Advance Newspaper*, where the author examines the success of UAVs and states that they may be opening a new era of flight in which man’s place is on the ground. David Wood, “Do We Really Need Fighter Pilots?”, *Staten Island Advance, November 3, 1997.*

[27] Joseph C. Anselmo, “Launch Upgrades Key to Milspace evolution”, *Aviation Week and Space technology*, September 1 1997, 48.

[28] William B. Scott, “Wargames Underscore Value of Space Assets for Military Ops”, *Aviation Week and Space Technology*”, 28 April 1997, 60.

[29] On-line, Internet, “Civil Reserve Air Fleet”, November 6 1997, Available on www.cqsc.army.mil/usaf/amc toobook/craf/data.htm.

[30] Ibid.

[31] Ibid.

Chapter 6

Conclusion

The new DOD space architecture envisioned for 2010-2025 established four core capabilities in space. Two of these, extremely high frequency development and broadband global broadcast are already part of the commercial industry's plans. As noted, three companies have received leases to build constellations that will utilize V-band, and 13 firms have obligated billions of dollars for systems that will provide a variety of broadband communications services. The third and fourth core requirements, mobile netted service and robust polar communications coverage, are also being satisfied by LEO satellites that are in polar orbits and will provide global cellular telephone services in 1998 and beyond with companies such as Motorola. As argued throughout this paper, the void identified in the space architecture report is not a factor if the commercial industries can fill the anticipated gaps that are destined to occur between 2003-2015. In reference to the frequency spectrum, the space architecture plan also states that the use of the Ka-band for both commercial and military space communications provides the greatest potential for commercial and military systems.[1] Cooperative efforts must also be applied to the allocation of frequency bands, which up until now has been a burden.

If UCAVs could take the place of a manned aircraft on the most politically sensitive sortie, these weapons would become a vital part of our precision engagement strategy. Commercial satellites offer the UCAV the opportunity to develop, mature, and deploy during a period that has been identified as risky for satellite communications. The DOD should not hesitate in developing commercial links with our civilian counterparts so that the UCAV system can evolve and mature.

From the outside looking in, it should be obvious that the ongoing technology revolution is leading our military toward an increased sophistication, where satellite technology and some derivative of UAVs are certainly included in the future. There is no denying the cost of these weapon systems is great, yet they are necessary, as we become more accustomed to quick decisive battles with very few casualties. Based on these assertions, there has never been a more appropriate time for the United States Department of Defense to seek a coalition with our civilian counterparts. This coalition could easily be incorporated into a Satellite Reserve Air Fleet that matures with our military system as we move into the next century.

The UCAV that is destined to fly for this country is ideally suited for satellite command and control that can only be supported with a joint military-commercial venture. The commercial satellite industry will own the majority of satellites in orbit around the earth within the next 5-7 years. These satellites will offer the newest frequencies, high data rates, redundancy, survivability, flexibility, varied orbits, and most of all, an opportunity for the military to improve its capabilities by the better use of all space systems to support the military mission and UCAV future requirements.

Notes

[1] "Space Communications Architecture", 29 August 1996, 1, On-line, Internet, 6 November 97, available from http://www.acq.osd.mil/space/architect/space.html.

Glossary

ACTS	Advance Communications Technology Satellite
BDA	Bomb Damage Assessment
Bps	Bits per Second
C3	Command, Control, and Communications
COTS	Commercial off the Shelf
CRAF	Civil reserve Air Fleet
DARPA	Defense Advance Research Project Agency
FCC	Federal Communications Commission
GBS	Global Broadcast System
GCS	Ground Control Station
GEO	Geosynchronous Earth Orbit
ISL	Inter Satellite Links
LDR	Low Data Rate
LEO	Low Earth Orbit
LO	Low Observable
LOS	Line of Sight
MDR	Medium Data rate
MEO	Medium Earth Orbit
MILSATCOM	Military Satellite Communications
QDR	Quadrennial Defense Review
SAAS	School of Advanced Airpower Studies
SRAF	Satellite Reserve Air Fleet
UAVS	Unmanned Aerial vehicles
UCAV	Uninhabited Combat Air Vehicle
UHF	Ultra High Frequency

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